A highly efficient and general method for the ring-opening of aziridines with various nucleophiles in DMSO

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Ring-opening of aziridines with various nucleophiles (such as amines, thiols, and silylated nucleophiles) in DMSO under mild conditions without any catalyst afforded the corresponding products in good to excellent yields.

Introduction

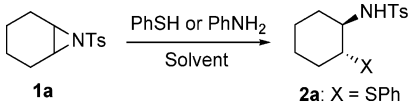
Ring-opening reactions of aziridines with nucleophiles are a useful protocol in organic synthesis, and many reagents have recently been developed to effect the opening of the aziridine ring.[1] However, most of these methods are complicated by the fact that a Lewis acid or strong base is necessary for the reaction to take place.[2] Moreover, different reaction conditions are needed for different aziridines and nucleophiles because of their varying reactivity and the structural complexity of the aziridines.[3–5] Recently, small molecules have been utilized as organocatalysts in the ring-opening reactions of aziridines with various nucleophiles.[6,7] For example, Hou has developed tributylphosphine-catalyzed ring-opening reactions of aziridines with nucleophiles.[6] However, the catalyst, Bu_3P, is not stable and is easily oxidized in air. Furthermore, a high catalyst loading (at least 10%) was necessary to achieve respectable yields; the yield and rate dramatically decreased if catalyst loading was reduced. In addition, we have developed tertiary amine catalyzed ring-opening reactions of aziridines with various nucleophiles, such as amines and thiols.[7] In these two examples, the organocatalysts initially form a complex with the aziridine, which acts as a 'trigger' for the reaction.[6,7]

Oriyama[8] recently reported that DMSO, when used as the solvent, acted as a nucleophilic activator of several organic transformations. Inspired by these results, we envisaged that DMSO may also be effective in the ring-opening reactions of aziridines with various nucleophiles. Herein, we disclose our preliminary results for this kind of transformation, which was performed in DMSO without any catalyst under mild conditions with a variety of nucleophiles.

Results and discussion

Initial studies revealed that without any catalyst, the reaction of aziridine **1a** with thiophenol proceeded smoothly in DMSO at 40 °C to afford the corresponding product in high yield (90%, Table 1, entry 1). The *anti*-stereochemistry of the product **2a** was confirmed by the coupling constants for the two cyclic methine protons at the *trans*-positions.[4] Further exploration showed that DMSO was the best solvent among those screened, and that the reaction worked most efficiently at 40 °C. No product was detected when this reaction was performed in water, due to the insolubility of aziridine **1a**. When aniline was used as the nucleophile, the reaction of **1a** also proceeded well in DMSO at 60 °C (85% yield, Table 1, entry 11). Reactions performed in MeCN and DMF showed inferior results (Table 1, entries 9 and 10).

Table 1 Reactin of aziridine **1a** with thiophenol or aniline under different solvents and temperatures



1a **2a**: X = SPh **2l**: X = NHPh

Entry	NuH	Solvent	Temp./°C	Time/h	Yield (%)[a]
1	PhSH	DMSO	40	1.5	90
2	PhSH	DMSO	25–30	1.5	24
3	PhSH	THF	40	18	17
4	PhSH	DMF	40	1.5	79
5	PhSH	MeCN	40	1.5	85
6	PhSH	H_2O	40	10	NR
7	PhSH	Toluene	40	18	13
8	$PhNH_2$	DMSO	50	10	57
9	$PhNH_2$	MeCN	50	10	16
10	$PhNH_2$	DMF	50	10	36
11	$PhNH_2$	DMSO	60	6	85

[a] Isolated yield based on aziridine.

A variety of aziridines and nucleophiles were examined for the ring-opening reactions using the optimized reaction conditions, and the results are summarized in Table 2. As shown in Table 2, this reaction is general, and useful for ring-openings of a range of aziridines **1** with both electron-withdrawing and electron-donating groups attached to the nitrogen atom. In most cases, reactions were very clean and the desired products were isolated in good to excellent yield. It is noteworthy that, in contrast to previous reports,[4–7] activated aziridines (such as **1a** and **1d**), as well as an unactivated aziridine (**1c**), were all suitable substrates for nucleophilic attack. For example, when aziridine **1c** reacted with thiophenol and aniline, the products were obtained in 80% and 68% yield, respectively (Table 2, entries 6 and 17). Although the reactions of aziridines with aromatic thiols or amines proceeded well under these conditions, reactions that employed aliphatic nucleophiles were sluggish (Table 2, entries 4 and 15). However,

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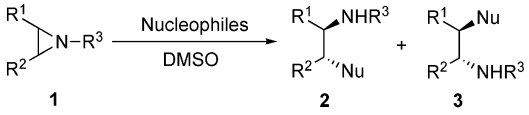
Table 2 Ring-opening reactions of aziridines with various nucleophiles in DMSO



1 2 3

1a: R^1, R^2 = -$(CH_2)_4$, R^3 = Ts; **1b**: R^1, R^2 = -$(CH_2)_3$, R^3 = Ts;
1c: R^1, R^2 = -$(CH_2)_4$, R^3 = Ph; **1d**: R^1, R^2 = -$(CH_2)_4$, R^3 = COPh;
1e: R^1 = ^{n}Bu, R^2 = H, R^3 = Ts; **1f**: R^1 = Ph, R^2 = H, R^3 = Ts;
1g: R^1 = *p*-ClC_6H_4, R^2 = H, R^3 = Ts.

Entry	Aziridine	Nu	Temp./°C	Time/h	Product	Yield (%)[a]
1	**1a**	C_6H_5SH	40	1.5	**2a**	90
2	**1a**	4-$MeOC_6H_4SH$	40	2	**2b**	90
3	**1a**	4-ClC_6H_4SH	40	2	**2c**	83
4	**1a**	$C_6H_5CH_2SH$	40	24	**2d**	15
5	**1b**	C_6H_5SH	40	5	**2e**	73
6	**1c**	C_6H_5SH	40	14	**2f**	80
7	**1d**	C_6H_5SH	40	5	**2g**	96
8	**1e**	C_6H_5SH	40	3.5	**2h**	96
9	**1e**	4-ClC_6H_4SH	40	2	**2i**	86
10	**1f**	C_6H_5SH	40	3.5	**2j/3j** (2.3 : 1)[b]	68
11	**1g**	C_6H_5SH	40	3.5	**2k/3k** (1 : 1)[b]	89
12	**1a**	$C_6H_5NH_2$	60	6	**2l**	85
13	**1a**	4-$MeOC_6H_4NH_2$	60	7	**2m**	77
14	**1a**	4-$FC_6H_4NH_2$	60	7	**2n**	92
15	**1a**	$C_6H_5CH_2NH_2$	60	24	**2o**	Trace
16	**1b**	$C_6H_5NH_2$	60	12	**2p**	62
17	**1c**	$C_6H_5NH_2$	60	24	**2q**	68
18	**1e**	$C_6H_5NH_2$	60	10	**2r**	96
19	**1f**	$C_6H_5NH_2$	60	6.5	**2s/3s** (1 : 5)[b]	92
20	**1g**	$C_6H_5NH_2$	60	10	**2t/3t** (1 : 6)[b]	92
21	**1a**	$TMSN_3$	40	12	**2u**	89
22	**1a**	TMSCl	40	9	**2v**	95
23	**1b**	$TMSN_3$	40	10	**2w**	93
24	**1e**	$TMSN_3$	40	10	**2x**	95
25	**1e**	TMSCl	40	10	**2y**	97

[a] Isolated yield based on aziridine. [b] Ratio was determined by ^{1}H NMR.

the conditions were suitable for the ring-opening reactions of aziridines with silyl nucleophiles. For example, reaction of **1a** with trimethylsilyl azide or chloride afforded the corresponding products in 89% and 95% yield, respectively (Table 2, entries 21 and 22). In the case of the unsymmetrically substituted aziridine **1e**, complete regioselectivity, with the attack of nucleophile on the less substituted aziridine carbon, was observed (Table 2, entries 8, 9, 18, 24, and 25). For substrates **1f** and **1g**, as previously reported,[1] it is reasonable that regioselectivity is not as specific as others due to an electronic effect (Table 2, entries 10, 11, 19, and 20). Thus, mixtures of regioisomers were generated, since both a steric effect and electron effect control the reaction process. For example, when aziridine **1f** or **1g** reacted with aniline under the optimized conditions (Table 2, entries 19 and 20), the major product was that resulting from nucleophilic attack on the benzylic position. We also carried out the reaction of aziridine **1a** with trimethylsilyl azide in the presence of 1.0 equiv. of DMSO at 40 °C in THF, giving 79% isolated yield of the desired product **2u** after 72 h. The reaction was retarded when 10% of DMSO was utilized under the conditions above.

As regards the role of DMSO in the ring-opening of aziridines with nucleophiles, although the mechanism is not clear since there is no supporting evidence at present, we suggest that DMSO may act as a Lewis base to activate the nucleophile during the reaction process, as previously reported.[8–10] For the reactions of aziridines with thiols or amines, we have previously reported that DABCO can react with aziridine to trigger that reaction.[7] Therefore, we treated aziridine **1a** with DMSO at 40 °C for 10 h, but no change was observed, which excludes the possibility that DMSO acts as a trigger in this transformation. In the reactions of aziridines with silyl nucleophiles, we believe that DMSO coordinates to the trimethylsilyl group to form hypervalent silicon compounds,[9,10] which are active towards further nucleophilic attack (Fig. 1).

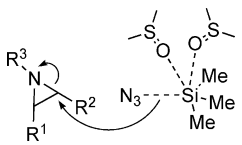


Fig. 1 Proposed mechanism for the reaction of aziridines with silyl nucleophiles.

Conclusions

In conclusion, we have developed an efficient and convenient method for the ring-opening of aziridines with various nucleophiles. This reaction has the following synthetic advantages: (1)

in contrast to the known ring-opening reactions of aziridines, the present procedure needs neither a base nor a metal catalyst; (2) both activated and unactivated aziridines are suitable substrates; (3) various nucleophiles, including thiols, amines, and trimethylsilyl azide or chloride, can be employed in this reaction; (4) the atom economy is high, as almost all of the reagent is consumed; (5) mild reaction conditions; and (6) ease of experimental operation. Further investigations for the desymmetrization of *meso*-aziridines with various nucleophiles are underway in our laboratory.

Experimental

All reactions were performed in test tubes under nitrogen atmosphere. Flash column chromatography was performed using silica gel (60 Å pore size, 32–63 μm, standard grade, Sorbent Technologies). Analytical thin-layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel impregnated with a fluorescent indicator (254 nm). Aziridines were prepared according to literature methods.[1] Solvents were redistilled prior to use in the reactions. Other commercial reagents were used as received.

General procedure

General procedure for the reactions of aziridines **1** with various nucleophiles: the nucleophile (1.0 equiv.) was added to a solution of substrate **1** (0.25 mmol) in DMSO (2.0 mL). The reaction mixture was stirred at 40 °C or 60 °C for the period of time indicated in Table 2. After the reaction was complete (as indicated by TLC,) the mixture was washed with water and extracted with ethyl acetate. The organic extracts were dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification by column chromatography on silica gel afforded the corresponding product. All the products are known compounds, and their data was identical to that in the literature.[4–7,11–14]

4-Methyl-*N*-(2-(phenylthio)cyclohexyl)benzenesulfonamide[6a] (2a). ^{1}H NMR (500 MHz, d^6-DMSO) δ 1.20–1.50 (m, 4H), 1.50–1.75 (m, 2H), 2.00–2.10 (m, 1H), 2.20–2.30 (m, 1H), 2.45 (s, 3H), 3.00 (t, $J = 11.4$ Hz, 1H), 3.10 (t, $J = 11.1$ Hz, 1H), 7.10–7.30 (m, 7H), 7.63 (d, $J = 8.2$ Hz, 2H), 7.80 (d, $J = 7.5$ Hz, 1H); EIMS: 361 (M^+); Calc. for $C_{19}H_{23}NO_2S_2$: C, 63.13; H, 6.41; N, 3.87. Found: C, 63.07; H, 6.48; N, 3.91%.

***N*-(2-(4-Methoxyphenylthio)cyclohexyl)-4-methylbenzenesulfonamide[7] (2b).** ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.26–1.31 (m, 3H), 1.57–1.61 (m, 3H), 1.96–1.99 (m, 1H), 2.31–2.33 (m, 1H), 2.45 (s, 3H), 2.67–2.68 (m, 1H), 2.88–2.90 (m, 1H), 3.80 (s, 3H), 5.27 (s, 1H), 6.77 (d, $J = 8.63$ Hz, 2H), 7.19 (d, $J = 8.66$ Hz, 2H), 7.30 (d, $J = 8.08$ Hz, 2H), 7.76 (d, $J = 8.11$ Hz, 2H).

***N*-(2-(4-Chlorophenylthio)cyclohexyl)-4-methylbenzenesulfonamide[12] (2c).** ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.26 (m, 3H), 1.39–1.40 (m, 1H), 1.56–1.63 (m, 2H), 1.98–2.01 (m, 1H), 2.21–2.23 (m, 1H), 2.44 (s, 3H), 2.92–2.93 (m, 1H), 2.99–3.00 (m, 1H), 5.27 (d, $J = 4.7$ Hz, 1H), 7.18–7.22 (m, 4H), 7.26–7.29 (m, 2H), 7.73 (d, $J = 8.20$ Hz, 2H).

***N*-(2-(Benzylthio)cyclohexyl)-4-methylbenzenesulfonamide[7] (2d).** ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.18–1.25 (m, 3H), 1.38–1.45 (m, 1H), 1.58–1.63 (m, 3H), 2.00–2.02 (m, 1H), 2.23–2.25 (m, 1H), 2.41 (s, 3H), 2.91 (m, 1H), 3.50–3.59 (m, 2H), 5.04 (s, 1H), 7.22–7.32 (m, 7H), 7.76 (d, $J = 8.4$ Hz, 2H).

4-Methyl-*N*-(2-(phenylthio)cyclopentyl)benzenesulfonamide[7] (2e). ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.47–1.51 (m, 1H), 1.54–1.60 (m, 1H), 1.65–1.71 (m, 2H), 2.09–2.14 (m, 2H), 2.43 (s, 3H), 3.27–3.34 (m, 2H), 4.80 (d, $J = 4.2$ Hz, 1H), 7.25–7.28 (m, 7H), 7.66 (d, $J = 8.1$ Hz, 2H).

***N*-(2-(Phenylthio)cyclohexyl)benzenamine[13] (2f).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.21–1.42 (m, 3H), 1.49–1.60 (m, 1H), 1.62–1.78 (m, 2H), 2.07–2.10 (m, 1H), 2.31–2.34 (m, 1H), 3.07–3.08 (m, 1H), 3.15–3.20 (m, 1H), 4.03 (s, 1H), 6.53 (d, $J = 7.84$ Hz, 2H), 6.68–6.70 (m, 1H), 7.10–7.19 (m, 2H), 7.25–7.27 (m, 3H), 7.36–7.42 (m, 2H).

***N*-(2-(Phenylthio)cyclohexyl)benzamide[6a] (2g).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.21–1.33 (m, 4H), 1.68–1.72 (m, 2H), 2.12–2.13 (m, 1H), 2.30–2.33 (m, 1H), 3.07–3.09 (m, 1H), 3.91–3.93 (m, 1H), 6.39 (d, $J = 7.8$ Hz, 1H), 7.22–7.25 (m, 3H), 7.36–7.44 (m, 5H), 7.68 (d, $J = 7.32$ Hz, 2H).

4-Methyl-*N*-(1-(phenylthio)hexan-2-yl)benzenesulfonamide[12] (2h). ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.83 (t, $J = 7.32$ Hz, 3H), 1.02–1.18 (m,4H), 1.31–1.41 (m, 1H), 1.58–1.69 (m, 1H), 2.39 (s, 3H), 2.78–2.80 (m, 1H), 3.12–3.17 (m, 1H), 3.29–3.39 (m, 1H), 4.90 (d, $J = 7.32$ Hz, 1H), 7.22–7.26 (m, 7H), 7.65 (d, $J = 7.84$ Hz, 2H).

***N*-(1-(4-Chlorophenylthio)hexan-2-yl)-4-methylbenzenesulfonamide[12] (2i).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.83 (t, $J = 7.32$ Hz, 3H), 0.98–1.24 (m, 4H), 1.31–1.41 (m, 1H), 1.58–1.61 (m, 1H), 2.40 (s, 3H), 2.78–2.81 (m, 1H), 3.12–3.17 (m, 1H), 3.24–3.33 (m, 1H), 4.98 (d, $J = 7.84$ Hz, 1H), 7.19–7.23 (m, 6H), 7.66 (d, $J = 8.28$ Hz, 2H).

4-Methyl-*N*-(1-phenyl-2-(phenylthio)ethyl)benzenesulfonamide[6a] (2j). ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.36 (s, 3H), 3.16–3.21 (m, 2H), 4.26–4.32 (m, 1H), 5.36 (d, $J = 3.92$ Hz, 1H), 7.05–7.12 (m, 4H), 7.18–7.30 (m, 6H), 7.50 (d, $J = 7.8$ Hz, 2H), 7.62 (d, $J = 7.8$ Hz, 2H).

4-Methyl-*N*-(2-phenyl-2-(phenylthio)ethyl)benzenesulfonamide[6a] (3j). ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.43(s, 3H), 3.35–3.40 (m, 2H), 4.13 (t, $J = 7.32$ Hz, 1H), 4.75 (s, 1H), 7.05–7.12 (m, 4H), 7.18–7.30 (m, 6H), 7.50 (d, $J = 7.8$ Hz, 2H), 7.62 (d, $J = 7.8$ Hz, 2H).

***N*-(1-(4-Chlorophenyl)-2-(phenylthio)ethyl)-4-methylbenzenesulfonamide[12] (2k).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.37 (s, 3H), 3.12–3.14 (m, 2H), 4.21–4.28 (m, 1H), 5.55 (s, 1H), 7.00 (d, $J = 7.8$ Hz, 2H), 7.10–7.12 (m, 2H), 7.16–7.26 (m, 7H), 7.49 (d, $J = 7.8$ Hz, 2H).

***N*-(2-(4-Chlorophenyl)-2-(phenylthio)ethyl)-4-methylbenzenesulfonamide[12] (3k).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.43 (s, 3H), 3.30–3.35 (m, 2H), 4.14 (t, $J = 7.84$ Hz, 1H), 4.92 (s, 1H), 7.03 (d, $J = 7.8$ Hz, 2H), 7.10–7.12 (m, 2H), 7.16–7.26 (m, 7H), 7.63 (d, $J = 7.8$ Hz, 2H).

4-Methyl-*N*-(2-(phenylamino)cyclohexyl)benzenesulfonamide[6a] (2l). ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.0–1.07 (m, 1H), 1.20–1.31 (m, 3H), 1.65 (d, $J = 11.76$ Hz, 2H), 2.0–2.04 (m, 1H), 2.15–2.18 (m, 1H), 2.44 (s, 3H), 2.90 (dt, $J = 9.76$, 2.92 Hz, 1H), 3.04 (dt, $J = 9.76$, 2.92 Hz, 1H), 3.43 (s, 1H), 5.04 (s, 1H), 6.47 (d, $J = 7.84$ Hz,

2H), 6.69 (t, $J = 7.32$ Hz, 1H), 7.11–7.13 (m, 2H), 7.27–7.29 (m, 2H), 7.75 (d, $J = 8.28$ Hz, 2H).

***N*-(2-(4-Methoxyphenylamino)cyclohexyl)-4-methylbenzenesulfonamide[7] (2m).** ^{1}H NMR (500 MHz, $CDCl_3$): δ 0.97–1.00 (m, 1H), 1.21–1.31 (m, 3H), 1.65–1.67 (m, 2H), 2.05–2.12 (m, 2H), 2.46 (s, 3H), 2.80–2.83 (m, 1H), 2.90–2.92 (m, 2H), 3.75 (s, 3H), 5.01 (d, $J = 4.1$ Hz, 1H), 6.46 (d, $J = 8.8$ Hz, 2H), 6.75 (d, $J = 8.9$ Hz, 2H), 7.32 (d, $J = 8.0$ Hz, 2H), 7.76 (d, $J = 8.2$ Hz, 2H).

***N*-(2-(4-Fluorophenylamino)cyclohexyl)-4-methylbenzenesulfonamide[7] (2n).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.04–1.29 (m, 4H), 1.64–1.66 (m, 2H), 1.97–1.98 (m, 1H), 2.13–2.17 (m, 1H), 2.42 (s, 3H), 2.83 (m, 1H), 2.94–2.98 (m, 2H), 5.08 (d, $J = 5.0$ Hz, 1H), 6.44–6.46 (m, 2H), 6.85–6.87 (m, 2H), 7.26–7.30 (m, 2H), 7.75 (d, $J = 8.2$ Hz, 2H).

4-Methyl-*N*-(2-(phenylamino)cyclopentyl)benzenesulfonamide[7] (2p). ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.26–1.46 (m, 2H), 1.68–1.71 (m, 2H), 1.88–1.90 (m, 1H), 2.17–2.21 (m, 1H), 2.42 (s, 3H), 3.40–3.51 (m, 2H), 4.91 (d, $J = 6.1$ Hz, 1H), 6.53–6.58 (m, 2H), 6.70–6.73 (m, 1H), 7.11–7.15 (m, 2H), 7.26–7.27 (m, 2H), 7.76 (d, $J = 8.2$ Hz, 2H).

***N*^{1},*N*^{2}-Diphenylcyclohexane-1,2-diamine[5d] (2q).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.22–1.28 (m, 2H), 1.38–1.42 (m, 2H), 1.76–1.78 (m, 2H), 2.33–2.36 (m, 2H), 3.18–3.20 (m, 2H), 3.81 (s, 2H), 6.60–6.62 (m, 4H), 6.68–6.72 (m, 2H), 7.15–7.17 (m, 4H).

4-Methyl-*N*-(1-(phenylamino)hexan-2-yl)benzenesulfonamide[14] (2r). ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.83 (t, $J = 6.84$ Hz, 3H), 1.02–1.20 (m, 4H), 1.31–1.39 (m, 1H), 1.45–1.50 (m, 1H), 2.41 (s, 3H), 3.04–3.05 (m, 1H), 3.12–3.14 (m, 1H), 3.35–3.37 (m, 1H), 3.92 (s, 1H), 4.79 (d, $J = 7.32$ Hz, 1H), 6.48 (d, $J = 8.32$ Hz, 2H), 6.70 (t, $J = 7.32$ Hz, 1H), 7.10–7.15 (m, 2H), 7.20–7.26 (m, 2H), 7.75 (d, $J = 8.32$ Hz, 2H).

4-Methyl-*N*-(1-phenyl-2-(phenylamino)ethyl)benzenesulfonamide[7] (2s). ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.38 (s, 3H), 3.12–3.18 (m, 1H), 3.29–3.38 (m, 1H), 4.35–4.40 (m, 1H), 5.10 (s, 1H), 5.52 (d, $J = 3.92$ Hz, 1H), 7.08–7.12 (m, 2H), 7.41–7.48 (m, 2H), 7.53–7.61 (m, 6H), 7.76 (d, $J = 8.32$ Hz, 2H), 7.83 (d, $J = 8.32$ Hz, 2H).

4-Methyl-*N*-(2-phenyl-2-(phenylamino)ethyl)benzenesulfonamide[7] (3s). ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.39 (s, 3H), 3.12–3.18 (m, 1H), 3.29–3.38 (m, 1H), 4.25–4.30 (m, 1H), 4.51 (s, 1H), 5.01 (t, $J = 6.36$ Hz, 1H), 6.45 (d, $J = 7.84$ Hz, 2H), 6.66 (t, $J = 7.36$ Hz, 2H), 7.01–7.12 (m, 6H), 7.50 (d, $J = 7.8$ Hz, 2H), 7.62 (d, $J = 7.8$ Hz, 2H).

***N*-(1-(4-Chlorophenyl)-2-(phenylamino)ethyl)-4-methylbenzenesulfonamide[14] (2t).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.34 (s, 3H), 3.08–3.18 (m, 1H), 3.24–3.31 (m, 1H), 4.41–4.46 (m, 1H), 5.72 (s, 1H), 5.79 (d, $J = 6.36$ Hz, 1H), 6.72 (d, $J = 8.28$ Hz, 2H), 7.14–7.28 (m, 5H), 7.41 (d, $J = 8.28$ Hz, 2H), 7.51 (d, $J = 8.32$ Hz, 2H), 7.75 (d, $J = 8.32$ Hz, 2H).

***N*-(2-(4-Chlorophenyl)-2-(phenylamino)ethyl)-4-methylbenzenesulfonamide[14] (3t).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.43 (s, 3H), 3.08–3.18 (m, 1H), 3.24–3.31 (m, 1H), 4.34–4.39 (m, 1H), 4.59 (s, 1H), 5.27 (t, $J = 5.4$ Hz, 1H), 6.41 (d, $J = 8.28$ Hz, 2H), 6.66 (t, $J = 7.32$ Hz, 1H), 7.01–7.08 (m, 3H), 7.20–7.24 (m, 5H), 7.69 (d, $J = 8.32$ Hz, 2H).

***N*-(2-Azidocyclohexyl)-4-methylbenzenesulfonamide[11b] (2u).** ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.18–1.31 (m, 4H), 1.63–1.68 (m, 2H), 2.00–2.03 (m, 2H), 2.43 (s, 3H), 2.92–2.96 (m, 1H), 3.08–3.10 (m, 1H), 5.18 (d, $J = 6.25$ Hz, 1H), 7.31 (d, $J = 8.28$, 2H), 7.81 (d, $J = 8.28$ Hz, 2H).

***N*-(2-Chlorocyclohexyl)-4-methylbenzenesulfonamide[11b] (2v).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.20–1.30 (m, 3H), 1.61–1.71 (m, 3H), 2.12–2.27 (m, 2H), 2.43 (s, 3H), 3.11–3.12 (m, 1H), 3.72–3.74 (m, 1H), 5.20 (d, $J = 4.88$ Hz, 1H), 7.30 (d, $J = 7.84$ Hz, 2H), 7.78 (d, $J = 8.32$ Hz, 2H).

***N*-(2-Azidocyclopentyl)-4-methylbenzenesulfonamide[11b] (2w).** ^{1}H NMR (500 MHz, $CDCl_3$): δ 1.36–1.41 (m, 1H), 1.59–1.69 (m, 3H), 1.95–2.00 (m, 2H), 2.44 (s, 3H), 3.37–3.42 (m, 1H), 3.70–3.73 (m, 1H), 4.72 (d, $J = 6.25$ Hz, 1H), 7.31 (d, $J = 7.8$ Hz, 2H), 7.79 (d, $J = 8.2$ Hz, 2H).

***N*-(1-Azidohexan-2-yl)-4-methylbenzenesulfonamide[11b] (2x).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.83 (t, $J = 7.32$ Hz, 3H), 1.06–1.26 (m, 4H), 1.34–1.48 (m, 2H), 2.43 (s, 3H), 3.30–3.40 (m, 3H), 5.01 (d, $J = 7.36$ Hz, 1H), 7.31 (d, $J = 7.80$ Hz, 2H), 7.78 (d, $J = 7.84$ Hz, 2H).

***N*-(1-Chlorohexan-2-yl)-4-methylbenzenesulfonamide[11b] (2y).** ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.84 (t, $J = 6.84$ Hz, 3H), 1.10–1.26 (m, 4H), 1.40–1.60 (m, 2H), 2.40 (s, 3H), 3.44–3.51 (m, 3H), 5.00 (d, $J = 8.32$ Hz, 1H), 7.31 (d, $J = 7.80$ Hz, 2H), 7.77 (d, $J = 7.80$ Hz, 2H).

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